# Promising Scientific Achievements in Science, Education and Production – 2022

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**NES Nová Dubnica s.r.o.**

**Monograph 1**

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## 4.1. General Provisions, State and Prospects of Renewable Energy

The concept of "energy" has been known for a long time. Humanity has been using various forms of energy for its existence since ancient times. Energy is the ability of a system to do work. There are several types of energy in nature, for example, kinetic energy, potential energy, thermal energy, nuclear fission energy, electrical energy. Currently, one of the most high-quality forms of energy is electricity. Its main advantage is its possible transformation into any other form of energy.

Hydrocarbon fuels (coal, oil and gas) have become widespread as a source of energy in the world. However, according to experts, the explored global reserves of traditional hydrocarbon fuels are capable of meeting global demand only for the next 60 years. Therefore, the development of new sources of energy is currently a priority task. All known sources of energy on earth can be conditionally divided into two types:

– non-renewable energy sources (traditional) are natural reserves of substances and materials that can be used by humans for energy production. Examples include nuclear fuel, coal, oil, gas. The energy of non-renewable sources, unlike renewable sources in nature, is in a bound state and is released as a result of purposeful human actions;

– renewable energy sources are energy sources based on constantly existing or periodically occurring energy flows in the environment. A typical example of such a source is solar radiation with a characteristic repetition period of 24 hours. Renewable energy is present in the environment in the form of energy that is not the result of purposeful human activity and this is its distinctive feature.

One of the most promising directions in the development of world energy at present is the use of renewable energy sources, which removes a number of problems that arise in the process of the functioning of traditional energy, including those related to the harmful impact on the environment. In a number of countries, the decommissioning of all nuclear power plants is planned, the alternative of which is the gradual replacement of decommissioned capacities with power plants based on renewable energy sources.

Renewable energy is a field of economics, science and technology, which covers the production, transmission, transformation, accumulation and consumption of electrical, thermal and mechanical energy due to the use of renewable energy sources as primary energy resources.

In general, all energy flows of renewable energy sources are divided into two main groups:

– direct energy of solar radiation;

– secondary manifestations of solar radiation energy in the form of wind energy, hydropower, thermal energy of the environment, biomass energy, etc.

The main advantages of renewable energy sources compared to traditional non-renewable sources are:

– practically inexhaustible resources;

– reducing the negative impact on the environment, including emissions of various pollutants, greenhouse gases, radioactive and thermal pollution, etc.

The main factors limiting the use of non-traditional renewable energy sources are:

– low energy flow density, which is, for example, for solar energy on the Earth's surface $1{,}36 \cdot 10^{-3}$ MW/m$^2$ , wind power at a wind speed of 10 m/s – $6 \cdot 10^{-4}$ MW/m$^2$ , geothermal - $3 \cdot 10^{-8}$ MW/m$^2$, while for NPP energy – 0.2 MW/m$^2$;

– significant unevenness of energy production over time and its use;

– relatively high capital intensity of power plants and the cost of produced electricity.

Need for widespread use of renewable energy sources is determined by the rapid growth of the need for electrical energy, which, according to forecasts, should increase by 2 times by 2030 and 4 times by 2050 compared to 2000; exhaustion of explored reserves of organic fuel in the foreseeable future; the crisis state of the environment in connection with pollution by nitrogen and sulfur oxides, carbon dioxide, dust particles from fuel combustion, radioactive and thermal pollution, etc.

Renewable energy sources have fundamental differences, so their effective use becomes possible on the basis of scientifically developed principles of transformation of renewable energy sources into types needed by consumers. There are always flows of renewable energy in the environment, therefore, in the process of developing renewable energy, it is necessary to focus on local energy resources, choosing the most efficient ones. The use of renewable energy sources should be multivariate and complex, which allows to accelerate the economic development of regions. For example, a good basis for the use of renewable energy sources can be agro-industrial complexes, where the waste of animal husbandry and crop production is the raw material for obtaining biogas, as well as liquid and solid fuel, fertilizer production.

***Classification of renewable energy sources***

An important characteristic of energy resources is the quality of the energy source. Usually, the quality of energy sources, both renewable and non-renewable, refers to the proportion of energy that can be converted into mechanical work. For example, electrical energy has a high quality, because with the help of an electric motor, more than 95% of it can be converted into mechanical work. The quality of thermal energy released during the burning of fuel at traditional thermal power plants or extracted from the hot depths of the Earth is quite low, since only about 30% of the heat of combustion of fuel or the enthalpy of hot water and steam from the depths of the Earth is ultimately transformed into mechanical work. According to this feature, renewable energy sources can be divided into three groups:

– renewable sources of mechanical energy, the main of which are hydropower, wind energy, wave and tide energy. In general, the quality of these sources is high and they are usually used for the production of electricity. The coefficient of use of wind energy is up to 30%, hydropower - 60%, wave and tidal energy - 75%.

– thermal renewable energy sources, the main of which are direct solar energy, biofuel energy. The maximum share of the heat of such sources, which can be converted into mechanical work, is determined by the second law of thermodynamics. In practice,

approximately half of the heat allowed by the second law of thermodynamics can be converted into work. For modern steam turbines, for example, this value does not exceed 35%.

– renewable energy sources based on photon processes, which include sources using photosynthesis and photoelectric phenomena. It is very important to achieve a high efficiency of energy conversion in the entire spectrum of solar radiation, and in practice the efficiency of photodetectors does not yet exceed 25%.

In particular, the following types of non-traditional renewable sources can be distinguished for electricity production [1]:

– biomass (more precisely, solid fuel from biomass);

– geothermal energy;

– solid combustible waste of cities and industry and agriculture;

– energy of tide and ocean waves;

– wind energy;

– biogas (gas obtained as a result of anaerobic activity of bacteria using various raw materials and animal and human waste);

– solar energy based on various technologies: photoelectric converters; solar power plants (thermal);

– other secondary combustible waste (municipal and industrial) as non-renewable resources.

As can be seen from this list, not all components included in it can be qualified as non-traditional restorative. In particular, as regards the VER of industry and agriculture, it is, as a rule, industrial waste in the form of emissions of combustible substances or low-temperature heat, which are formed as a result of underutilization of burned organic fuel. Thus, their use is only more rational ways of using organic fuel, which is a direct energy saving. The same can be said for the last item in the list. Thus, non-traditional renewable energy sources should now include only sources that have an exclusively direct origin from the Sun and the Earth. Such sources are considered to be: solar electromagnetic radiation energy, wind energy, geothermal energy, biomass energy, sea wave energy, hydropower, extraction of heat from the environment and some others.

***Energy potential of renewable energy sources***

One of the most important characteristics of renewable energy sources is their energy potential - an indicator that determines the amount of energy inherent in the corresponding type of renewable energy sources. To evaluate the energy resources of renewable energy sources, possible for use, the following types of energy potential of renewable energy sources are distinguished [2]:

– theoretical, characterizing the total amount of energy;

– technical - a part of the theoretical potential, which in principle can be used with the help of modern devices;

– cost-effective - part of the technical potential, which is currently expedient to use, based on economic, social, environmental and other factors.

Quantitative indicators of energy resources of renewable sources of the planet are shown in table 4.1.1 [1; 3].

Table 4.1.1

Energy potential of renewable energy resources of the planet

| Renewable energy resources | Energy potential of renewable energy resources, billion tons of renewable energy resources/year | | |
|---|---|---|---|
| | Theoretical | Technical | Economically effective |
| Radiant energy of the Sun | 86000 | 5 | 1 |
| Thermal energy of seas and oceans | 7500 | 1 | 0.1 |
| Wind energy | 860 | 5 | 1 |
| Hydropower, in particular: | 6,065 | 3 | 1.52 |
| Energy of watercourses | 3 | 2.91 | 1.5 |
| Wave energy | 3 | 0.05 | 0.01 |
| Energy of tides | 0.065 | 0.04 | 0.01 |
| Biomass energy, in particular: | 40 | 2.55 | 2.0 |
| Forests | 15 | 1.5 | 1.5 |
| Plants | 10 | 1.0 | 0.5 |
| Algae | 15 | 0.05 | 0 |
| Geothermal energy | 16 | 0.4 | 1,2 |
| In total | 94422.065 | 16.95 | 5.2 |

The primary task for the successful implementation of Ukraine's tasks regarding the large-scale use of energy from renewable sources is to establish the energy potential of each type of renewable energy sources throughout the territory of Ukraine, for which a single information and analytical system with extended functions is being created, which allows to quickly solve the issue of the effectiveness of the introduction of energy equipment in specific area.

Energy resources of renewable energy sources are available practically throughout the territory of Ukraine. The main components of renewable energy in Ukraine include wind energy, solar energy, small hydropower, bioenergy, geothermal energy and environmental energy. The total annual technical energy potential of renewable energy sources of Ukraine in terms of conventional fuel amounts to about 98 million t.u.p. (Table 4.1.2), which is more than 50% of total energy consumption in Ukraine at present and 30% of energy consumption in 2030.

Annual indicators of the technical energy potential of the main areas of energy development of renewable sources in Ukraine are shown in Table 4.1.2 [4].

Table 4.1.2

Energy potential of renewable sources in Ukraine

| No. n/p | Areas of RES development | Annual technical energy potential | |
|---|---|---|---|
| | | billion kW×h/year | million t.p.a./year |
| 1 | Wind energy | 79.8 | 28.0 |
| 2 | Solar energy | 38.2 | 6.0 |
| 3 | Small hydropower | 8.6 | 3.0 |
| 4 | Bioenergetics | 178 | 31.0 |
| 5 | Geothermal heat energy | 97.6 | 12.0 |
| 6 | Environmental energy | 146.3 | 18.0 |
| Total volumes of replacement of traditional renewable energy sources at the expense of RES | | 548.5 | 98.0 |

***The current state and prospects for the development of renewable energy***

Renewable energy sources are used in both developed and developing countries. Great success in the development of renewable energy sources has been achieved by countries where renewable energy has received comprehensive state economic and legislative support, and significant funds are invested in the development of renewable energy sources, including the development of new technologies. At the beginning of the XXI century. the share of all renewable energy sources (including traditional hydropower, firewood) in world energy consumption was about 14%, and in electricity consumption - 19%. Intensive growth in the use of energy from non-traditional renewable energy sources, especially at the beginning of the 21st century, is characteristic of most developed and many developing countries. Thus, the share of electricity produced from non-traditional renewable energy sources in 2016 in EU countries (in total production): in Denmark – 12.1%, Finland – 13.1%, Hungary – 4%, Greece – 2.8 %, Italy – 2.8%, Spain – 2.8%, Germany (in 2007) – 14.2%, which amounted to 87.6 billion kWh , including: small hydroelectric stations – 20, 7 billion kWh , wind power plants - 39.5, biomass and biogas thermal power plants - 23.8, solar batteries - 3.5, geothermal - 0.1. IN Japan's total contribution to electricity production from non-traditional RES, which was 1.2% in 2010, is planned to increase to 3% by 2010, and to 10% by 2030. By 2020, China plans to increase the share of non-traditional energy sources in the country's fuel and energy balance to 16%. Practically all developed countries and many developing countries have national programs aimed at stimulating the accelerated development of renewable energy sources. Ensuring energy security is a serious motivation for the development of renewable energy sources for many countries, especially those that depend on the import of traditional energy resources. The cost of many technologies for the use of renewable energy sources and the resulting energy is steadily decreasing due to their improvement and the increase in the scale of production. Non-traditional renewable energy sources are becoming increasingly competitive in the following energy sectors: electricity generation; heat supply; complex energy supply of autonomous consumers. By the middle of the XXI century. non-

traditional renewable energy sources can become one of the most important energy resources. Their contribution to the energy balance of many countries can reach 40–50%. Given that many non-traditional renewable energy sources are characterized by the instability of the energy potential (variability of wind speed, solar radiation intensity, river flows, etc.), they are used in combined energy systems in combination with each other and with traditional energy sources. In addition, renewable energy sources in local heat and power supply systems are used together with various types of thermal and electric energy accumulators, as well as with hydrogen-based storage systems, which increases the efficiency of renewable energy sources and ensures uninterrupted energy supply to consumers. At the same time, renewable energy sources may become one of the main sources of hydrogen production from water in the future.

The main factors that determined the development of renewable energy sources in the world are the need to:

– ensuring energy security of countries;

– reduction of harmful emissions generated in the process of using traditional energy sources;

– increase in consumption of organic raw materials for non-energy needs;

– conservation of energy reserves for future generations.

Ukraine has significant potential for the development of renewable energy. The same can be said about other alternative traditional sources of energy, such as mine methane, peat, brown coal, waste potential of domestic and industrial waste, etc. All regions of the country have the opportunity to use non-traditional renewable energy sources , however, despite the significant amount of adopted laws, programs of regulatory acts and other documents, the implementation of non-traditional renewable energy sources in the country is proceeding too slowly, the contribution to the country's energy balance is insignificant .

There are many reasons for this state of affairs, the main of which is the lack of a system of economic stimulation of the transition to the use of non-traditional materials restorative sources energy, the declarative nature of normative legal acts without specific implementation mechanisms, as well as low executive discipline. It cannot be said that nothing is being done in this direction in the country, but what is being done is not enough to compensate for negative trends such as the global increase in energy prices, the increase in the country's energy dependence and environmental pollution.

Without introducing new types of non-traditional renewable energy sources , without investing in technologies, without developing production based on new technologies, the country preserves technological backwardness and may lose its chance to join the European community.

Among the factors contributing to the development of non-traditional restorative sources energy in Ukraine can be called:

– increase in the price of traditional energy carriers;

– increasing the requirements of environmental norms and standards;

– the possibilities of implementing the mechanisms of the Kyoto Protocol for financing projects for the implementation of non-traditional renewable energy sources;

– improving the possibility of joining the European community;

– the need to replace worn-out fixed assets.

Targeted state support for the development of non-traditional renewable energy sources , as shown by the experience of developed countries, is the basis for the implementation of development programs of each of their types. The pace of development of unconventional renewable energy sources will depend on the ability to access long-term financing. The increase in the competitiveness of non-traditional renewable energy sources will occur not only due to the improvement of technologies and the expansion of production volumes of non-traditional renewable energy sources , but also due to a decrease in the availability of traditional energy sources and, accordingly, their prices. Already today, some types of non-traditional renewable energy sources are competitive, others are at a close distance, so even political support at the state level, an appropriate favorable environment can give a significant impetus to their development.

Among the priority types of non-traditional renewable energy sources that can already be successfully developed. The use of low- potential energy of the environment transformed into high- potential energy with the help of heat pumps has a significant perspective . In a more distant perspective, Ukraine can move to a hydrogen economy, which is considered in the world as the basis of the future technological revolution. For this , Ukraine needs to carry out appropriate scientific research and develop hydrogen technologies, especially since the achievements of Ukrainian scientists in this field are quite significant.

For the further development of renewable energy in Ukraine to the world level and the large-scale development of energy from renewable sources, it is necessary to solve the problems of scientific and technological support for the development of each of the main types of renewable energy sources, first of all, the creation of an effective base of fundamental and applied scientific research and a design and construction base for development and implementation of new equipment and technologies of renewable energy.

To effectively solve the problems of the development of renewable energy in Ukraine, it is necessary to form a national energy policy with the help of [5]:

– improvement of the legislative and regulatory and technical base of renewable energy, taking into account the peculiarities of the development of each type of renewable energy sources.

– development of the foundations of the economic stimulating policy of the state, based on the implementation of a preferential policy for producers and consumers of energy from renewable sources, the use of effective financing mechanisms;

– formation and financing of relevant state programs, including measures to create demonstration objects;

– supporting the activities of relevant public organizations;

– adaptation of the provisions of state programs on the development of RES to the requirements of the European Union;

– creation of an educational system - both special technical in all areas of renewable energy, and for the formation of environmental and energy- saving consciousness of the population;

– formation of a positive image of renewable energy in the public mind to overcome the backwardness and mistrust of potential investors and consumers using all available mass media.

### 4.2. Solar Energy

Solar energy is one of the promising, rapidly developing areas of renewable energy use. At the current stage of the development of solar energy, the problems of efficient use of solar radiation energy due to the use of advanced technologies come to the fore. The advantages of the practically inexhaustible source of solar radiation energy when using it as a primary local energy resource are the possibility of using the source of thermal energy on most areas of the Earth's surface and the possibility of direct conversion of solar radiation energy into electrical energy.

Solar energy in its utilitarian sense belongs to the renewable energy resources of the Earth's civilization. Sunlight does not require extraction and transportation, it is weightless, silent and, as a rule, harmless, and its disposal does not create direct waste and does not disturb the thermal balance of the planet. Therefore, the fundamental difference between solar energy and all traditional energy carriers that are used is its flawlessness from the point of view of chemical, thermal and other types of environmental pollution. The already listed properties make it a unique candidate for the main role in the energy strategy of the new millennium [6].

This strategy focuses on the creation of powerful solar power plants , both ground-based and space-based, as well as the widespread construction of small solar modules that decentralize the production of heat and electricity. Practical steps, which are starting successfully in most developed countries, confirm its optimality, and the trends of modern world development suggest an almost tenfold increase in the use of solar energy during each subsequent decade.

Advantages of solar energy:

– general availability and inexhaustibility of the source;

– theoretically, complete safety for the environment (however, in our time, harmful substances are used in the production of photovoltaic cells and in them).

Disadvantages of solar energy:

– fundamental problems: due to the relatively small value of the solar constant, solar energy requires the use of large areas of land for power plants (for example, for a power plant with a capacity of 1 GW, it can be several tens of square kilometers). However, this disadvantage is not so great, for example, hydropower takes much larger areas of land out of use. In addition, photovoltaic elements at large solar power plants are installed at a height of 1.8-2.5 meters, which allows the land under the power plant to be used for agricultural purposes, for example, for cattle grazing. The problem of finding large areas of land for solar power plants is solved in the case of the use of solar balloon power plants, suitable both for land and sea and for high-altitude basing; the

flow of solar energy on the Earth's surface strongly depends on latitude and climate. In different areas, the average number of sunny days per year can vary greatly;

– technical problems: the solar power plant does not work at night and does not work efficiently enough in the morning and evening twilight. At the same time, the peak of electricity consumption falls precisely in the evening hours. In addition, power plant capacity can fluctuate rapidly and unexpectedly due to weather changes. To overcome these shortcomings, it is necessary to either use effective ones electric batteries (to date, this is an unsolved problem), or build hydroaccumulating stations, which also occupy a large area, or use the concept of hydrogen energy , which is also still far from economic efficiency. The problem of the dependence of the power of a solar power plant on the time of day and weather conditions is solved in the case of solar balloon power plants; high price of solar photovoltaic cells. Probably, with the development of technology, this shortcoming will be overcome. IN From 2000 to 2015, prices for photovoltaic cells decreased by an average of 4% per year; insufficient efficiency solar cells (probably will be increased soon); the surface of the photopanels must be cleaned of dust and other contaminants. With their area of several square kilometers, this can cause difficulties; the efficiency of photovoltaic elements drops significantly when they are heated, so there is a need to install cooling systems, usually water; after 30 years of operation, the efficiency of photovoltaic cells begins to decrease.

***Classification of methods and means of solar radiation energy conversion***

A solar power plant is a power plant that converts the energy of solar radiation into other types of energy (for example, heat or electricity).

The advantages of solar radiation energy compared to traditional types of fuel are as follows [7]:

– the source of energy is practically inexhaustible;

– the possibility of using the energy of solar radiation on most parts of the Earth's surface as a local energy source;

– the possibility of direct conversion of solar radiation energy into electrical energy;

– the possibility of obtaining high temperatures;

– the possibility of accelerating action in photochemical processes.

In solar energy, two main practical directions of using solar energy can be distinguished:

– conversion of solar energy into electrical energy, including: photoelectric method of conversion (electromagnetic radiation of the optical range of the Sun is converted into direct current electricity); thermodynamic method of conversion (concentrated solar energy is used to obtain steam, which, rotating a turbine generator, produces electricity);

– conversion of solar energy into thermal energy, including: heating; hot water supply.

In Ukraine, the following areas of solar energy use have been identified as the most promising at the moment:

– solar electricity or direct conversion of solar energy into direct current electrical energy using photoreceptors;

– solar thermal energy or direct conversion of solar energy into low-potential thermal energy without prior concentration of the flow of solar radiation (for hot water supply of objects, communal household and technological heat supply, needs of agriculture).

***Solar power industry***

Solar electricity is based on the conversion of solar energy into electricity using photovoltaic and thermodynamic methods. Solar power plants are divided into:

– photoelectric and thermoelectric, in which the energy of solar radiation is directly converted into electrical energy of direct current;

– thermodynamic with multiple conversion of solar energy: first into heat, then into mechanical and electrical energy.

Photoelectric conversion of solar energy is currently one of the priority areas of using solar energy, which is due to the following:

– the possibility of obtaining electricity in almost any area;

– environmental cleanliness of energy conversion;

– a significant period of work;

– low maintenance costs;

– the independence of solar energy conversion efficiency from installed capacity.

One of the ways to improve photoenergy is the creation of concentrating photocells. The system of concentration of solar energy consists directly of concentrators and a system of tracking the position of the Sun, because concentrating photocells perceive only direct solar radiation. Today, silicon is used to create concentrating solar cells. Thus, elements with a degree of concentration k=11 and an efficiency of 20% were created on the basis of silicon in Australia.

In recent years, photoenergy has received significant development thanks to progress in solving the main problems: increasing the efficiency of solar photoconverters and reducing the cost of their production.

One of the important areas of modern solar power industry is the centralized production of electricity at solar power plants. All solar power plants are created on the basis of solar thermal power plants, in which, with the help of optical systems, solar energy is concentrated to heat the working medium to a temperature that ensures the efficient operation of thermal machines.

Thermodynamic solar power plants, which are the most common at present, are based on three main principles:

– sunny tower-type power plants with a central receiver-steam generator, on the surface of which solar radiation from flat mirrors-heliostats is concentrated;

– solar power plants of the modular type, in which evacuated receivers - tubes with heat carrier (steam generators) are placed in the focus of parabolocylindrical concentrators;

– combined solar power plants are solar -thermal power plants that produce electrical and thermal energy; a power plant of one type or another is combined with a thermal power plant.

The most acceptable in operation are solar thermal power plants with a central receiver, which use a moderate amount of conventional construction materials and

increase the energy output by 20-60 times. They can compete with traditional power plants, and it is predicted that they will become more efficient in the future.

***Solar thermal energy***

In the modern world, solar energy is widely used for heat supply, including hot water supply and heating, as well as for cooling , air conditioning, drying and other technological processes.

Solar heating systems are classified as follows:

– "active" solar heat supply systems using "active" installations based on solar collectors with circulation of the heat carrier, which can be used as liquid (water, salt solutions) and gas (air);

– "passive" solar heating systems, in which various structural elements of buildings are used as heat receivers of solar energy;

– combined solar heat supply systems, in which elements of "passive" and "active" solar heat supply are used.

Passive solar systems are simpler and cheaper compared to active ones, because they do not require additional devices for absorption, conversion and distribution of solar energy. Passive use of solar energy for heating buildings occurs due to planning, architectural and constructive solutions, when the entire building can be considered as a collector of solar heat.

In the passive system, the optimal orientation of the building should be approximately along the east-west axis, at least 50-70% of all windows should be on the south side, no more than 10% on the north side, living rooms should be located on the south side, etc. In addition in addition, special devices are provided - roofs - heat accumulators , convection systems, etc.

Active use of solar energy can be achieved with the help of a solar pond. Such ponds are good accumulators of solar energy. Due to the fact that the density of the salt solution in the lower layers is much higher compared to the upper ones, in such ponds there is practically no convection heat and mass exchange , as a result of which a layer of water with a high temperature is created in the bottom zone of the pond. This property of salt ponds can be used to obtain electrical energy.

Solar energy furnaces, pool heating, desalination of sea and salt water, production of distilled water, solar household furnaces, drying of agricultural products, etc., are based on the active use of the thermal action of the sun's rays.

***The potential of solar energy in Ukraine***

As a result of the processing of statistical meteorological data on the arrival of solar radiation, the specific energy indicators of the arrival of solar energy and the distribution of the energy potential of solar radiation for each of the regions of Ukraine were determined.

The average annual amount of total solar radiation per 1 $m^2$ of the surface in Ukraine ranges from 1070 $kW \times h/m^2$ in the northern part of Ukraine to 1400 $kW \times h/m^2$ and above in the Autonomous Republic of Crimea.

The potential of solar energy in Ukraine is high enough for wide implementation of both heat energy and photoenergy equipment in almost all regions. The period of effective operation of solar energy equipment in the southern regions of Ukraine is 7

months (from April to October), in the northern regions it is 5 months (from May to September). Photoelectric equipment can be operated efficiently throughout the year.

In the climate -meteorological conditions of Ukraine, the use of flat solar collectors, which use both direct and scattered solar radiation, is effective for solar heat supply. Concentrating solar collectors can be sufficiently effective only in the southern regions of Ukraine.

A sufficiently high level of ready-to-serial production and a wide range of possible applications of solar thermal energy equipment in Ukraine shows that for large-scale implementation and obtaining significant savings in fuel and energy resources, it is only necessary to increase the interest of manufacturers in the production of large batches of such equipment.

The conversion of solar energy into electrical energy in the conditions of Ukraine should be focused primarily on the use of photovoltaic devices. The presence of significant reserves of raw materials, industrial and scientific and technical base for the manufacture of photovoltaic devices can fully satisfy not only the needs of the domestic consumer, but also represent more than two-thirds of the manufactured products for export.

The given energy indicators from the arrival of solar radiation are basic when implementing solar energy equipment and are recommended for use primarily by designers of solar energy facilities for choosing the type of equipment (solar thermal, photovoltaic installations) and for establishing their optimal power and the term of effective operation of the equipment in specific area.

The total annual potential of solar energy on the territory of Ukraine is presented in table 4.2.1

Table 4.2.1

The total annual potential of solar energy on the territory of Ukraine

| No n/p | Regions | The potential of solar energy MW×h/year | | |
|---|---|---|---|---|
| | | General potential ($\times 10^9$) | Technical potential ($\times 10^7$) | The goal is economic potential ($\times 10^5$) |
| 1 | Vinnytsia | 30.8 | 14.8 | 2,3 |
| 2 | Volynsk | 21.8 | 10.5 | 1.6 |
| 3 | Dnipropetrovsk | 37.6 | 18 | 2.8 |
| 4 | Donetsk | 33 | 15.8 | 2.5 |
| 5 | Zhytomyr | 32.3 | 15.5 | 2.4 |
| 6 | Zakarpattia | 15.5 | 7.5 | 1,2 |
| 7 | Zaporizhzhia | 34.8 | 16.7 | 2.6 |
| 8 | Ivano-Frankivsk | 16.4 | 7.9 | 1,2 |
| 9 | Kyivska | 31.5 | 15.5 | 2.4 |
| 10 | Kirovohradsk | 28.8 | 13.8 | 2,2 |
| 11 | Luhansk | 34 | 16.3 | 2.5 |

| | | | | |
|---|---|---|---|---|
| 12 | Lviv | 25.4 | 12.2 | 1.9 |
| 13 | Mykolayivska | 32.5 | 15.6 | 2.4 |
| 14 | Odesa | 45.4 | 21.8 | 3,4 |
| 15 | Poltava | 31.9 | 15.3 | 2.4 |
| 16 | Rivne | 21.8 | 10.5 | 1.6 |
| 17 | Sumy | 26 | 12.5 | 2.0 |
| 18 | Ternopilsk | 16.3 | 7,8 | 1,2 |
| 19 | Kharkivska | 35.4 | 17 | 2.7 |
| 20 | Khersonsk | 38.4 | 18.4 | 2.9 |
| 21 | Khmelnytska | 24.3 | 11.6 | 1.8 |
| 22 | Cherkassy | 24.2 | 11.6 | 1.8 |
| 23 | Chernivtsi | 9.6 | 4.6 | 0.7 |
| 24 | Chernihivska | 34.2 | 16.4 | 2.6 |
| 25 | Crimea | 36.5 | 17.5 | 2.7 |
| | **In total** | **718.4** | **345.1** | **53.8** |

The main ways and methods of solving the problems of solar energy in Ukraine are:

– conducting scientific fundamental and applied research;

– research and design development and organization of their implementation;

– training of specialists;

– creation of specialized infrastructure on the basis of already existing educational, design and construction, and research organizations;

– development of a legal framework that will contribute to the implementation of developments based on the use of solar energy, including the access of solar power plants to the electric and heat networks of energy companies ;

– creation of a certification and metrological base;

– the development of domestic industrial production and the creation of a base for the manufacture of technical devices and equipment, installation, operation, repair and service;

– introduction of mandatory state regulation (management and control) of the processes of profile preservation, reorientation and use of existing production facilities after the reconstruction of enterprises and their expansion in accordance with modern requirements;

– formation of the legislative space for the provision of tax benefits for domestic manufacturing enterprises for the export of solar energy elements and the application of a strict price and tax policy regarding the import of solar energy elements in Ukraine;

– provision of priority financing of research and development works on solar energy, which are carried out to order within the framework of state and industry programs of all levels;

– involvement of advanced technologies in the field of solar energy based on mutually beneficial domestic and foreign investment projects;

– creation of an effective state pricing system aimed at increasing the share of wages in the price of products and increasing the real wages of workers in the solar energy industry.

### 4.3. Small Hydropower

Small hydropower, which is the most developed of the non-traditional renewable sources of electricity, allows you to use the significant hydropower potential of small rivers and tributaries , water supply systems, and in many cases to provide local power supply to remote areas or settlements, especially in underdeveloped countries and countries that are breaking up , with a limited centralized power supply system.

Advantages of small hydropower:

– sufficient available volumes of reconstruction and construction of small hydroelectric power stations;

– significant service life and high operational reliability;

– predictability and security of work modes;

– high maneuverability and readiness ratio;

– the possibility of full automation of the operation process;

– low depreciation costs;

– minimal impact on the environment;

– minimal impact on the landscape and minor alienation of land plots;

– additional opportunities for fishing, irrigation, water supply, managed protection of territories from floods.

***Methods and means of energy conversion and consumption of small watercourses***

Small hydroelectric power stations are highly efficient generators of electricity. In most cases, they are used as multi-purpose objects that meet the needs of the electric power industry and other sectors of the national economy: land reclamation, water transport, water supply, fisheries, etc.

A small hydroelectric power station is a complex of buildings and equipment, with the help of which the energy of the water flow is transformed into electrical energy. A hydroelectric station consists of hydrotechnical structures that ensure the concentration of water flow and the creation of the necessary pressure, and energy equipment that converts the energy of the water flow into electrical energy.

In Ukraine, according to capacity, small hydropower plants are conditionally divided as follows [8]:

– micro - hydroelectric stations - with a capacity of up to 100 kW (0.1 MW). They are intended for energy supply of individual enterprises, remote villages. The range of these stations is up to 1 (sometimes 2-5) km. Energy distribution is carried out with a voltage of up to 10 kV, the most used voltage is 0.2-0.4 kV. The construction part is distinguished by its simple design, the hydromechanical equipment consists of one or two turbines.

– mini-hydroelectric stations - from 100 to 1000 kW (0.1-1 MW). Intended for a group of consumers located within a radius of 20-25 km, or for energy supply of a relatively large enterprise. Electricity is distributed with a voltage of up to 10 kV.

Hydromechanical equipment consists of two or three turbines. They often work in parallel with the central power system;

– small hydroelectric stations - from 1000 to 10000 kW (1-10 MW). Intended for energy supply of consumers within a radius of 50-60 km. They work in parallel with the central power system.

In terms of the amount of pressure used, hydroelectric ones are small stations are classified as follows:

– low-pressure (micro - hydroelectric stations – up to 15 m, mini-hydroelectric stations – up to 20 m, small – up to 25 m);

– medium pressure (micro - hydroelectric stations – 15-50 m, mini- hydroelectric stations – 20-100 m, small – 25-130 m);

– high -pressure (micro - hydroelectric stations - more than 25 m, mini hydroelectric stations - more than 100 m, small - more than 130 m).

According to the method of creating pressure, hydroelectric power stations are built according to the following schemes:

– rowing;

– derivative;

– dam -derivative (mixed).

It should be noted that the introduction of small hydroelectric power stations practically does not create a negative effect, while large hydroelectric power stations , during the construction of which large areas of productive land are removed from land use, can negatively affect the state in the economic, ecological and social spheres of the regions where they are implemented.

***Hydroelectric work stations in energy systems***

The operation of hydroelectric power stations in the power system has certain peculiarities, caused by the dependence on the river flow and on the modes of operation of multi-purpose reservoirs, as well as restrictions on the conditions of the bottom beef and environmental protection. Hydroelectric reservoirs stations, depending on the useful capacity, can carry out daily, weekly, seasonal and multi-year regulation. At the same time, however, in a year that is unfavorable in terms of water level (usually a low-water year with 90–95% availability is taken as an estimate), hydroelectric stations must provide the estimated guaranteed energy output to cover their zone of the power system load schedule [8].

The reservoir of daily regulation allows to redistribute the natural daily flow to ensure the non-uniform mode of operation of hydroelectric stations in order to cover the peak part of the load schedule.

Under the conditions of reduced electrical loads in the power system on weekends during weekly regulation, power and electricity production by hydroelectric stations are reduced , and unused runoff is accumulated in the reservoir and used on weekdays, ensuring increased energy yield hydroelectric stations .

With seasonal and multi-year regulation of the reservoir in the period of low water, hydroelectric the station provides coverage of the peak part of the daily load schedule due to the natural inflow of water into the reservoir during the day and the use of the useful volume previously accumulated by the reservoir.

In conditions of complex use of the reservoir, accounting for the requirements of other water users can to a certain extent affect the operating mode of the hydroelectric power plant station. In the presence of restrictions, for example, related to the provision of a constant guaranteed minimum discharge in the lower beef, the hydroelectric plant will also partially operate in the basic part of the load schedule with the capacity determined by this discharge.

In the flood period, in order to maximize the energy use of water and reduce its idle discharges, usually all units of the hydroelectric station work at full capacity non-stop, producing the maximum possible amount of electricity without conducting daily regulation, covering the basic part of the power system load schedule. This makes it possible to save fuel in general, although in this period some thermal power plants are forced to work in an uneven mode, including in the peak part of the load schedule.

At hydroelectric power stations with a reservoir that has a significant useful capacity, it is advisable to place an emergency reserve system with a long operating time. At hydroelectric power stations , a load reserve system is also placed to maintain the frequency in power systems. The operation of combined power systems with a higher specific gravity of the hydroelectric station depends on the regulation of the flow through the reservoirs, as well as on the regulation of the energy output when working together in the power system of the cascades of hydroelectric plants due to the natural asynchrony of the annual flow.

The hydroelectric station is an important system-forming factor. Creation of large hydroelectric cascades stations and high-voltage transmission lines for issuing their power in many cases became the basis for the formation of combined power systems.

The operation of a hydroelectric station is characterized by high reliability, the probability of emergency situations at hydroelectric stations is much lower than at thermal power stations, in which emergency situations are associated with the use of extremely high temperatures and pressures in the technological cycle, larger fuel reserves, etc.

***Small hydropower resources***

The methods of determining the energy resources of small watercourses are based on the determination of the energy potential of each of them and further generalization of data on the energy potential of small watercourses within the district, region, and country.

The starting data for calculating the energy potential of a small river is information on the average long-term flow.

The water energy of small rivers is used to obtain electrical energy when using low-power hydroturbines. The basis of the operation of the hydropower plant is the conversion of falling water energy into mechanical energy. Unlike other power plants, no fundamental limitations (thermodynamic or dynamic) interfere with the energy of the falling water from the turbine. At a given location of the hydrostation, the height of the water drop is a known constant value, and the flow of water when the water pipes are filled can be practically constant. The real power of the hydro turbine is close to the theoretical power, which ensures the maximum power of the necessary power equipment. The location of the hydrostation should ensure a sufficiently high flow of

water and the height of its fall. For this, an annual precipitation level of at least 40 cm is required, which falls fairly evenly throughout the year, the topography of the area and the territory for the reservoir are determined. If these conditions are met, hydropower will be an effective source of electricity.

Modes of operation of small hydroelectric power stations have limited possibilities of regulating the flow and correspond to the regime of the water flow of the river. In dry and winter periods, such hydroelectric stations operate with significantly less capacity (within the limit equal to zero) than the installed capacity.

***The energy potential of small hydropower in Ukraine***

Ukraine has powerful small-river hydropower resources - the total small-river hydropower potential of Ukraine is about 12.5 billion kW×h, which is about 28% of the total hydro potential in all years of Ukraine.

A database has been created on the distribution of the energy potential of small rivers in the regions of Ukraine. Fluctuations of the averaged data on the overall potential in Ukraine are quite insignificant, while the data on the technical and feasibility-economic potential of small years require clarification - in normal situations at least once every 5 years, and in exceptional cases - annually.

The main advantage of small hydropower is the cheapness of electricity generated at hydroelectric power stations; the absence of a fuel component in the process of obtaining electricity when implementing small hydroelectric power plants gives a positive economic and environmental effect.

The primary source of energy for small hydropower is the hydro potential of small rivers; the upper limit of the capacity of hydropower equipment is 30 MW. According to the international classification according to the UN standard, small hydroelectric plants include hydroelectric plants with a capacity of 1 to 30 MW, mini -hydroelectric plants - from 100 to 1000 kW, and micro - hydroelectric plants - no more than 100 kW.

When using the hydro potential of small rivers of Ukraine, it is possible to achieve a significant saving of fuel and energy resources, and the development of small hydropower will contribute to the decentralization of the general energy system, which will remove a number of problems both in the energy supply of remote and hard-to-reach areas of the countryside, and in the management of giant energy systems; at the same time, a whole set of problems in the economic, ecological and social spheres of life and management in rural areas, including district centers, will be solved.

Small, mini- and micro- hydroelectric plants can become a powerful basis of energy supply for all regions of Western Ukraine, and for some districts of Zakarpattia and Chernivtsi regions - a source of complete self -energy supply .

To solve the problems of the development of small hydropower, Ukraine has sufficient scientific and technical potential and significant experience in the field of design and development of structures of hydroturbine equipment, research on the hydropower potential of small rivers, and the solution of water management and environmental problems during the construction of hydroelectric power stations. Ukrainian enterprises have the necessary production potential for the creation of domestic small hydroelectric equipment stations.

The hydropower potential of small rivers of Ukraine is shown in Table 4.3.1 [9].

Table 4.3.1

Hydropower potential of small rivers of Ukraine

| No n/p | Regions | Solar potential | | |
|---|---|---|---|---|
| | | General potential | Technical potential | The goal is economic potential |
| 1 | Vinnytsia | 360 | 238 | 108 |
| 2 | Volynsk | 115 | 76 | 35 |
| 3 | Dnipropetrovsk | 101 | 67 | 30 |
| 4 | Donetsk | 189 | 125 | 57 |
| 5 | Zhytomyr | 336 | 222 | 101 |
| 6 | Zakarpattia | 4532 | 2991 | 1357 |
| 7 | Zaporizhzhia | 51 | 33 | 15 |
| 8 | Ivano-Frankivsk | 399 | 263 | 120 |
| 9 | Kyivska | 200 | 132 | 60 |
| 10 | Kirovohradsk | 170 | 112 | 51 |
| 11 | Luhansk | 436 | 288 | 131 |
| 12 | Lviv | 1814 | 1197 | 544 |
| 13 | Mykolayivska | 157 | 104 | 47 |
| 14 | Odesa | 38 | 25 | 11 |
| 15 | Poltava | 396 | 261 | 119 |
| 16 | Rivne | 304 | 201 | 91 |
| 17 | Sumy | 298 | 197 | 89 |
| 18 | Ternopilsk | 427 | 282 | 128 |
| 19 | Kharkivska | 268 | 177 | 80 |
| 20 | Khersonsk | 2 | 2 | 1 |
| 21 | Khmelnytska | 304 | 200 | 91 |
| 22 | Cherkassy | 331 | 219 | 99 |
| 23 | Chernivtsi | 884 | 583 | 265 |
| 24 | Chernihivska | 178 | 118 | 54 |
| 25 | Crimea | 211 | 139 | 63 |
| | **In total** | **12501** | **8252** | **3747** |

## 4.4. Wind Energy

Wind energy is a method of obtaining electrical energy using the wind. The means of obtaining wind energy are wind turbines (wind generators, wind installations), which are combined into so-called wind power plants. Wind energy is a branch of renewable energy that specializes in using the kinetic energy of the wind. This is one of those ways of using environmental energy that has been known since ancient times.

The source of wind energy is the Sun, since it is its activity that causes the formation of wind. The Earth's atmosphere absorbs solar radiation unevenly due to the heterogeneity of its surface and the different angle of incidence of light in different latitudes at different times of the year. Air expands and rises, forming currents. Where the air is heated more, these flows rise higher and concentrate in areas of low pressure, while cooler air stays below, creating areas of high pressure. The difference in atmospheric pressure causes air to move from an area of high pressure to an area of low pressure at a proportional speed. We call this movement of air wind.

In order to make the best use of wind energy, it is important to have a thorough understanding of daily and seasonal changes in wind, the change in wind speed depending on the height above the earth's surface, the number of wind gusts in short periods of time, and also have statistical data for at least the last 20 years. Only 1-2% of the total amount of solar energy is converted into wind energy. This amount exceeds the annual world energy demand by five times. Modern technology makes it possible to use only horizontal winds that are located close to the Earth's surface and have a speed of 12 to 65 km/h.

The main difference between such a power plant and traditional (thermal, nuclear) is the complete absence of raw materials and waste. The only main requirement is a high average annual wind level. The capacity of modern industrial wind generators reaches 6 MW.

***Principles of wind energy conversion***

A wind power plant is a complex of technical devices for converting the kinetic energy of the wind flow into any other type of energy. The components of a wind power plant include the actual wind unit (a wind engine complete with one or more working machines), an accumulative or reserve device and systems automatic control and regulation of work modes. In some cases, a backup non-wind engine is used.

A wind engine is an engine that uses the kinetic energy of the wind to produce mechanical energy. A rotor, windmill, drum, etc. are used as the working body of a wind engine, which perceives the energy of the wind flow and converts it into mechanical energy of shaft rotation. Depending on the type of working body and its position relative to the wind flow, there are carousel (or rotary) wind engines, drum-type and vane-type.

A container filled with water or batteries of electrochemical accumulators are often used as a storage device; inertial batteries can be used for short-term energy storage and leveling of power consumption with slight changes in wind speed. A duplicating non-wind engine (usually an internal combustion engine) is used in periods of no wind energy flow and in those cases when, due to a decrease in wind speed, the power developed by the wind engine becomes lower than the nominal or insufficient to power the entire connected load with electricity.

Automatic control and regulation systems are used to turn on and off the wind turbine (depending on the wind and load modes, the degree of filling of the reserve tank with water, battery charge, etc. ), to control the operation of the main elements of the wind turbine, to coordinate the modes of joint or parallel operation wind and heat engines , etc.

There are special-purpose wind turbines - pumping or water-lifting, electric, charging, mill, and complex use - wind power and wind electric. In power wind turbines, the mechanical transmission of the wind engine drives the executive machines; in electric wind turbines, the generated electricity is transmitted to the electric motor of the executing machines. Depending on the type and characteristics of wind engines and working machines, wind turbines can be slow-speed, medium-speed and high-speed. The installed (calculated) power of the wind turbine depends mainly on the diameter of the wind wheel and the wind speed indicator. Wind turbines work with widely varying frequency of rotation of the windmill and, accordingly, power.

The transformation of the kinetic energy of the air flow when using wind energy equipment is carried out through its interaction with the working bodies of wind turbines, which can be performed in the following form:

– blades (flat, concave or with an aerodynamic profile);

– cylinders of A. Fletner;

– oscillating objects, for example, cables;

– systems with electrode grids of an electro-hydraulic dynamic generator.

The most common working bodies of wind turbines are blades with an aerodynamic profile. Wind turbines with working bodies in the form of oscillating objects and an electro-hydraulic dynamic generator are in the experimental stage. Research results [10, 11] show that such wind turbines are characterized by a low coefficient of wind energy utilization and the complexity of aggregating with the load.

***Classification of wind turbines***

Different types of wind energy equipment are used to use wind energy. The wind energy system first converts wind energy into mechanical energy, and then, if necessary. In electric. Functionally, wind turbines can be divided as follows:

– network wind power plants;

– autonomous wind power plants;

– wind turbines for performing mechanical work.

According to the directions of use, wind turbines are classified as follows:

– wind turbines and wind farms operating in the network (power system) of public use (network wind power plants and wind power plants);

– wind turbines operating in a local (autonomous) system in parallel with other power plants (diesel generator, small hydroelectric plant, solar battery, etc.);

– wind turbines for individual or group electricity supply;

– wind turbines for thermal energy production;

– wind turbines for the production of mechanical energy.

From the standpoint of structural and technological features, as well as development trends, wind turbines are conditionally divided into two groups [11]:

– small power wind turbine (up to 100 kW);

– wind power plant of medium high power (100 kW and more).

The features of the first group are due to the specifics of the market of this category of wind turbines, designed for individual consumers, and the impossibility (or limited possibilities) of professional maintenance led to the need for maximum

simplification and reduction in the cost of the construction of units. At the same time, the indicators of reliability and autonomy of work must remain at the highest level.

The wind turbines of the second group are characterized by common technological solutions, which are conditioned by the requirements for working in the power grid and the large dimensions of the wind turbines. At the same time, the high unit cost of units of this class is compensated by a decrease in the specific cost of 1 kW of installed capacity.

Structurally, wind turbines are classified according to two main features:

– the geometry of the windmill;

– the position of the windmill according to the direction of the wind.

***State and prospects of wind energy development***

In most developed countries, under the conditions of state stimulation of electricity production based on renewable energy sources, significant progress has been achieved in the construction and use of wind power plants in recent years.

Thanks to the implementation of scientific and technical achievements, the increase in the capacity of wind power plants, which combine a number of wind power plants, already at the beginning of the XXI century. the cost of electricity produced by wind power plants has decreased to 6-7 cents per kWh and has practically equaled the cost of electricity from a thermal power plant, and will be lower if additional costs related to environmental factors are taken into account. Specific capital investments, which are incurred per 1 kW of installed capacity, in powerful wind power plants (about 1,000 USD/kW) are less than in coal-fired thermal power plants.

Further reduction in the cost and increase in the efficiency of wind power plants is achieved by increasing the power of wind power plants and wind power plants, increasing the technical and economic indicators of wind power plants when implementing new scientific and technical solutions. Therefore, the development of wind power plants is directed by increasing the unit power of wind power plants and their number in the structure of wind power plants and, accordingly, in the total power of the wind power plant. The modular arrangement of wind power plants with the increase of unit capacity in recent years to 5 MW and more creates favorable conditions for their operation in combined power systems, allows to increase their reliability and efficiency. The most important indicator – the utilization ratio of the installed capacity – has increased to 25%, and according to forecasts, it may reach 30% by 2030.

The construction of wind power plants on the shelf in coastal, mainly shallow water areas in Denmark, the Netherlands, Sweden, Great Britain and other countries has been widely developed.

Due to its availability, wind energy is widely used in small wind energy, in local energy supply systems for consumers.

In Ukraine, there is a need and there are conditions for the rapid development of wind energy. However, Ukraine ranks 14th among European countries in terms of the level of wind energy use.

The total capacity of all wind power plants in Ukraine in 2017 was 557 MW. Developed by the National Academy of Sciences of Ukraine together with the National Space Agency of Ukraine, "Supplement to the Energy Strategy of Ukraine for the period

until 2030 in terms of the development of wind energy" envisages the construction of wind power plants with a total capacity of 16,000 MW in Ukraine by 2030.

***Wind energy resources***

Since the 1950s, the world has been working on the creation of a wind cadastre of territories. The main energy characteristic of the wind is its speed. Since wind speeds are constantly changing, when choosing sites for the construction of wind turbines, the daily, monthly and seasonal distribution schedules in a certain area are first of all considered. When conducting wind energy calculations, the direction of winds is also taken into account, that is, the characteristic directions of wind speeds in a given area during the year. The wind rose is a particularly important consideration when building powerful wind farms or when there is a significant concentration of wind energy equipment in a given area.

In order to assess the perspective of the implementation of wind energy equipment in a certain area, it is necessary to carry out calculations of theoretically possible, technically achievable and economically feasible energy resources of wind energy.

***Wind energy potential in Ukraine***

Ukraine has powerful wind energy resources: the annual technical wind energy potential is 30 billion kW×h.

As a result of the processing of statistical meteorological data on the speed and repeatability of the wind speed, the territory of Ukraine was zoned according to wind speeds, and the specific energy potential of the wind at different heights was determined according to the zone zones.

The given data are basic for the implementation of wind energy equipment and are intended for use by designers of wind energy facilities to establish the optimal power of wind units and back energy (electrical or mechanical) for its effective production in a specific area.

In the conditions of Ukraine, with the help of wind turbines, it is possible to use 15÷19% of the annual volume of wind energy that passes through the cross section of the surface of the windmill. The expected volume of electricity production from 1 $m^2$ of the cross-sectional area of the windmill in promising regions is 800÷1000 kW×h/$m^2$ per year.

The application of wind turbines for the production of electricity on an industrial scale is most effective in regions of Ukraine where the average annual wind speed is > 5 m/s: on the Azov-Black Sea coast, in Odesa, Kherson, Zaporizhzhia, Donetsk, Luhansk, Mykolaiv regions and in the Carpathian region.

The operation of low-speed multi- bladed wind turbines with increased torque for mechanical work ( grinding grain, raising and pumping water, etc. ) is effective in almost the entire territory of Ukraine.

The wind energy industry of Ukraine has sufficient experience in the production, design, construction, operation and maintenance of both wind energy installations and wind energy stations; the country has a sufficiently high scientific and technical potential and a developed production base. Recently, the development of the wind

energy sector has been facilitated by state support, which ensures the implementation of initiatives to improve the legislation, management structure, and create favorable conditions for domestic and foreign investors.

The implementation of state national programs in the field of wind energy for 2030 provides for the total annual production of electricity at wind power stations and autonomous wind installations of about 10.71 million MW×h; which will provide about 2.5 percent of the total annual electricity consumption in Ukraine.

Table 4.4.1

Specific energy potential of wind energy in Ukraine

| No. of the district | Average annual wind speed, $V_{average}$, m/s | Height, m | Natural wind potential, kW×h/m² year | Technically achievable wind potential, kW×h/m² year |
|---|---|---|---|---|
| 1 | <4.25 | 15 | 1120 | 200 |
| | | 30 | 1510 | 280 |
| | | 60 | 2030 | 375 |
| | | 100 | 2530 | 460 |
| 2 | 4.5 | 15 | 2010 | 390 |
| | | 30 | 2710 | 520 |
| | | 60 | 3640 | 700 |
| | | 100 | 4540 | 850 |
| 3 | 5.0 | 15 | 2810 | 520 |
| | | 30 | 3790 | 690 |
| | | 60 | 5100 | 860 |
| | | 100 | 6350 | 975 |
| 4 | 5.5 | 15 | 3200 | 620 |
| | | 30 | 4320 | 830 |
| | | 60 | 5810 | 1020 |
| | | 100 | 7230 | 1150 |

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## ANNOTATION

## CHAPTER 1. MODERN BASICS OF ECONOMICS, MANAGEMENT AND TOURISM

### 1.1. Oksana Marchenko, Volodymyr Vorovka, Maryna Salnikova CLUSTER MECHANISMS OF THE IMPROVEMENT OF THE REGIONAL STRUCTURE OF THE TOURISM INDUSTRY

The mechanisms of the formation of the innovative tourist clusters as the competitive advantage of the regional structure and the development of tourism have been considered in the research. The author's method of the determination of the effectiveness of the tourist cluster has been described. The measures of the improvement of the regional structure and the increase of the effectiveness of the functioning of tourism industry have been proposed.

**Keywords:** tourist cluster, mechanisms of management, tourist resources.

### 1.2. Olha Pikhotska NON-STATE PENSION FUNDS ON THE FINANCIAL MARKET SERVICES OF UKRAINE

The functioning of non-state pension funds was studied, the main indicators of their activity were analyzed. The analysis of the structure of invested pension assets showed that pension funds follow a moderate investment strategy in their activities. The main factors that negatively affect the functioning of non-state pension funds are identified and measures are proposed, the implementation of which will contribute to the further growth of their role in the financial market of Ukraine.

**Keywords:** non-bank financial institutions, non-state pension funds, invested pension assets, system of non-state pension provision.

### 1.3. Sofiya Vasulyuk, Ihor Franiv DEVELOPMENT OF BIOINDUSTRY AS A COMPONENT BIOECONOMY

It has been proven that the development of the bio-industry through the use of new knowledge-based technologies can ensure the emergence of completely new products and adapt existing processes and products in accordance with the needs of a sustainable economy. As an advantage in the development of the bioindustry, a number of aspects that are significant for the economy can be singled out, namely: increased employment, diversification of the economy, development of peripheral regions, the emergence of new types of products and the creation of new materials and biofuels, a reduction in the cost of production, a reduction in dependence on fossil energy resources, the use of reusable products and processing. It has been proven that the expansion of the practical value of the biotechnological industry is due to the socio-economic needs of society (food security, environmental pollution, shortage of raw materials and energy resources, development of new methods of diagnosis and therapy), which cannot be solved with the help of traditional methods, and therefore require the involvement of new technologies to support and improve the quality of human life, while the bioindustry plays the role of a valuable platform for their development and advancement.

**Key words:** bioeconomy, bioindustry, biotechnologies, innovations, sustainable development

**CHAPTER 2. INNOVATIVE AND MODERN FOUNDATIONS OF PEDAGOGY AND PSYCHOLOGY**

**2.1. Erika Kutsyn CLASSIFICATION OF MUSIC THERAPY**

The new Ukrainian school needs a teacher who has a whole arsenal of professional competences to create a constructive environment for the conditions of learning in speech therapy classes with children with speech disorders. The use of music therapy in the professional activities of music teachers and speech therapists helps to solve non-standard pedagogical tasks and contributes to the creation of a favorable social and psychological microclimate.

**Keywords.** Music therapy, receptive, active, professional activity.

**CHAPTER 3. THE LATEST BASICS OF AGRICULTURAL DEVELOPMENT**

**3.1. Roman Miroshnyk, Iryna Bahlai DEVELOPMENT OF AGRICULTURE OF UKRAINE IN MODERN CONDITIONS**

In the modern domestic economy, the agricultural market is an important branch of the national economy, which provides the population of Ukraine and the world with food products. The trends in the development of agriculture over the last decade have been studied: the reduction in the number of agricultural enterprises and employed workers in this field, the growth of sales volumes and the increase in cultivated areas. The impact of the war in Ukraine on agriculture is considered, as well as the prospects for the future development of the agricultural market.

**Key words:** agriculture, sown areas, market, development, grain.

**CHAPTER 4. Serhyy Onyshchenko INTEGRATED USE OF NON-TRADITIONAL AND RENEWABLE ENERGY SOURCES IN THE ELECTRICAL NETWORKS OF UKRAINE**

The world community considers the use of non-traditional and renewable energy sources as one of the most promising ways to solve the growing problems of energy conservation. The presence of an inexhaustible resource base and ecological purity of non-traditional renewable energy sources are their defining advantages in the conditions of depletion of organic fuel resources and growing rates of environmental pollution. The paper analyzes the state and prospects for the development of alternative energy in the world and in Ukraine, and conducts research on the specifics of using renewable energy from the sun, wind, and water.

**Keywords:** renewable energy sources, wind energy, solar energy, small hydropower.

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